METHOD FOR MANUFACTURING SEMICONDUCTOR DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on Japanese Patent Applications No. 2004-107859 filed on Mar. 31, 2004, and No. 2004-352010 filed on Dec. 3, 2004, the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a method for manufacturing a semiconductor device.

BACKGROUND OF THE INVENTION

[0003] A method for manufacturing a semiconductor device with a semiconductor substrate by which an epitaxial film is filled in trenches to form a doped layer having a high aspect ratio is disclosed in Japanese Patent No. 3485081. Further, a method for manufacturing a semiconductor substrate by which an epitaxial film is filled in trenches to form a doped layer when a super-junction structure (P/N column structure) is formed in a drift region in a vertical type MOS transistor is disclosed in Japanese Unexamined Patent Publication No. 2003-124464.

[0004] In the above device, a P-type silicon layer as an epitaxial film was filled in trenches of an N-type silicon substrate to form a diode structure. In this case, when a defect (i.e., a void) occurs in the epitaxial film filled in the trenches, a breakdown occurs at an upper portion of the void, which results in reducing a breakdown voltage.

[0005] In this manner, the influence of defects in the filled epitaxial film reduces the performance of a device. To be more detailed, the influence of defects reduces the breakdown voltage of the above-described super-junction structure (P/N column structure) and produces crystalline defects caused by filled defects (voids) to reduce a breakdown/junction leakage current yield and leaves resist in the portions of defects in the trenches to cause contamination in the process.

SUMMARY OF THE INVENTION

[0006] In view of the above-described problem, it is an object of the present invention to provide a method for manufacturing a semiconductor device with a semiconductor substrate. The substrate includes an epitaxial film filled in a trench with void-less structure.

[0007] A method for manufacturing a semiconductor device includes the steps of: forming a trench in a semiconductor substrate; and forming an epitaxial film on the substrate including a sidewall and a bottom of the trench so that the epitaxial film is filled in the trench. The step of forming the epitaxial film includes a final step before the trench is filled with the epitaxial film. The final step has a forming condition of the epitaxial film in such a manner that the epitaxial film to be formed on the sidewall of the trench has a growth rate at an opening of the trench smaller than a growth rate at a position of the trench, which is deeper than the opening of the trench.

[0008] In the above method, the growth rate of the epitaxial film at the opening of the trench is lower than that at a position of the trench deeper than the opening of the trench. Therefore, the epitaxial film is prevented from closing the opening of the trench so that the epitaxial film is filled in the trench without any void. Thus, the above method provides the substrate including the epitaxial film filled in the trench with void-less structure.

[0009] Further, a method for manufacturing a semiconductor device includes the steps of: forming a trench in a semiconductor substrate; and forming an epitaxial film on the substrate including a sidewall and a bottom of the trench so that the epitaxial film is filled in the trench. The step of forming the epitaxial film includes a final step before the trench is filled with the epitaxial film. The final step has a forming condition of the epitaxial film in such a manner that a mixuture of a silicon source gas and a halogenide gas is used for forming the epitaxial film.

[0010] In the above method, the halogenide gas works as an etching gas, and the etching rate of the halogenide gas is controlled by supply of the gas. Therefore, the etching rate of the epitaxial film at the opening of the trench is higher than that at a position of the trench deeper than the opening of the trench. Thus, the growth rate of the epitaxial film at the opening of the trench is lower than that at a position of the trench deeper than the opening of the trench. Therefore, the epitaxial film is prevented from closing the opening of the trench so that the epitaxial film is filled in the trench without any void. Thus, the above method provides the substrate including the epitaxial film filled in the trench with void-less structure.

[0011] Preferably, the step of forming the epitaxial film further includes a first step and an etching step. The first step is such that the epitaxial film is formed on the bottom and the sidewall of the trench to have a predetermined thickness. The etching step is such that a part of the epitaxial film at an opening of the trench is etched by the halogenide gas so that the opening of the trench is enlarged. More preferably, the final step has a second forming condition of the epitaxial film in such a manner that the epitaxial film is formed under a control of a chemical reaction. More preferably, the first step is performed under a predetermined vacuum pressure lower than that of the final step. Furthermore preferably, the predetermined vacuum pressure of the first step is in a range between 1000 Pa and 1×10^{-3} Pa.

[0012] Preferably, the step of forming the epitaxial film further includes a first step. The first step is such that the epitaxial film having an impurity doped in the epitaxial film is formed on the bottom and the sidewall of the trench to have a predetermined thickness. The final step is such that the epitaxial film having no impurity doped or a low concentration impurity doped in the epitaxial film is formed to fill an inside of the trench. The low concentration impurity of the epitaxial film in the final step has an impurity concentration lower than that in the first step. In this case, the epitaxial film is filled in the trench with void-less structure, and further, the impurity in the epitaxial film can be formed uniformly.

[0013] Preferably, the step of forming the epitaxial film further includes a first step and a vapor phase diffusion step. The first step is such that the epitaxial film having an impurity doped in the epitaxial film is formed on the bottom and the sidewall of the trench to have a predetermined thickness. The vapor phase diffusion step is such that an